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Aquanautics

Contract N00014-87-C-0335

A04696 NTU

QUARTERLY REVIEW: Engineering, October - December '87

PROJECT: DARPA

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PROJECT OBJECTIVE: To demonstrate the technology of oxygen extraction from seawater by designing an underwater vehicle powered by a fuel cell and oxygen supplied by Aquanautics system.

STATUS AT THE END OF PREVIOUS QUARTER: Please refer to previous quarter's report. In brief, pumping power required for cell was measured and scale up experiments revealed that the SU cell (420 cm^2) did have some problem in providing space-time-yield whereas MP cells did perform equivalent to or better than EOC.

EXECUTIVE SUMMARY: Major improvements were achieved in the power output relationship of the electrochemical cell. A tenfold increase in output (from 0.15 l/m^2 of cell to 1.5 l/m^2) at a given power input (100 watt-min/l). See attached figure. This has been due to:

1) use of higher conductivity carrier solution
2) use of electrocatalysis (see John Kerr's report)
3) optimization

Oxygen produced at such operating conditions has been used in an Al-O_2 fuel cell in a small-scale integration.

EOC Power Consumption	4.5 watts
Fuel Cell Power Output	better than 17.25 watts

Progress During This Quarter:

1. Modelling: A computer model relating no. of cells, oxygen output/unit cell area, energy consumed by EOC to produce unit volume of oxygen (watt-min/l), energy required for carrier pumping, energy required for seawater pumping and excess power generated was developed. The model provided an excellent direction in the scientific research activity as it showed the importance of low carrier flow rate and high oxygen output.

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2. Technical Improvements:

A. Electrochemical Engineering Input: The effects of higher conductivity solution and graphite vs. Ti as current collector on cell performance have been evaluated. As expected, the higher conductivity led to an output which is about three to four times that at lower conductivity. The effect is less pronounced at lower current densities. Graphite also held up better at higher operational voltages.

B. Chemical Engineering Output: Experiments varying flow rate of carrier fluid and concentration of the carrier were conducted to arrive at operating conditions for minimum hardware requirements. The final operating point after 24 hours continuous operation (repeated three times) was:

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EOC Power	125 watt.min/l
Output	1.5 l/m^2 of cell
Carrier flow	12 l/m^2 of cell
Conc. of Carrier	400 mM
Supporting Electrolyte	1.5 M KCL
Carrier Pumping Power @ 10% pump efficiency	20 watt-min/l

3. Scale Up: Most of the progress made was either demonstrated initially in the MP cell (100 cm^2) or scaled up to the MP cell from laboratory size (25 cm^2). The performance of MP cells was equivalent to or better than the performance of the laboratory size cell.

4. Incorporation of Electrocatalyst: A major development came out of the scientific research regarding use of an electrocatalyst to improve kinetics. This innovation was verified and incorporated in the MP cell resulting in an improved performance:

1. Excess power increased by 17%
2. Power and output steady for 24 hours
3. Cell voltage dropped from 0.8V to 0.5V allowing Ti to be used as current collector.

The operating point with mediator is 102 watt-min/l @ 1.5 l/m^2 of cell, with similar carrier pumping cost as before. The attached figure shows stepwise improvement of the performance of the cell.

5. Fuel Cell: A 3-cell Al-air fuel cell stack was received from Eltech. Aquanautics personnel were trained to use the fuel cell by Eltech's engineers. The fuel cell was installed and tested. The fuel cell provides about 400 w-min/l of O_2 consumed.

6. Pump-motor Research: Carrier pump and gas blowers were acquired and have been found to provide energy efficiency better than or equal to design point values.

Plan for the quarter January-March 1988:

i) Small Scale Integration: Oxygen produced from Aquanautics system (EOC) will be used to produce power by Eltech's fuel cell (3 EOC and 1 fuel cell).

ii) Loader: Oxygen transfer through the gill cartridge membrane will be carried out.

iii) Unloader: An unloader will be designed and tested for full size demonstration unit.

iv) Control System Design: Power distribution and control system design will be carried out and various parts will be procured.

v) MP Cell Scale Up: Full system will need 30 MP cells. The final configuration is to be determined by testing parallel/series combinations. This activity may continue beyond this quarter.

vi) Fuel Cell Delivery/Testing: 20 cell fuel cell stack will be delivered and tested.

vii) System Design and Hardware Design: Prototype unit to house all the subcomponents will be designed.

AQUANAUTICS CORPORATION

OXYGEN SYSTEMS

Progress on Power vs Oxygen Output